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TWO GENERATIONS OF CANADIAN AIRBORNE ACTIVE IMAGING SYSTEMS: ALBEDOS AND ELVISS

by

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ABSTRACT

Search and rescue (SAR) and general surveillance missions pose a serious challenge to conventional imaging systems used by current aircraft crews. These systems, which include common CCD cameras, image intensifier devices and thermal imaging sensors, must often work in low-light level and low-visibility conditions to find and identify targets. A new airborne imaging technology has been designed to overcome several of these limitations. The recent developments in laser diode arrays, laser diode beam collimation and gatable micro-channel plate intensifiers have made it possible to build a compact active imaging system, called the Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS). To demonstrate its potential, the system was installed on a helicopter and tested in various scenarios in October 1995. ALBEDOS proved particularly efficient at night and in degraded weather conditions. In addition, it was demonstrated that range gating, aside from eliminating most of the light backscattered by aerosols, provided near-total immunity to blooming effects, particularly in situations where conventional highly sensitive cameras are blinded.

The current operational scenarios require to enhance surveillance capability over large areas of coverage, to optimize the detection of humans and small objects and improve the effectiveness of the search aircraft. Thus, a second-generation system is currently developed and combines the benefits of two complementary imaging sensors. The Enhanced Low-light level Visible and Infrared Surveillance System (ELVISS) consists of an improved range-gated active imager and a high-quality thermal imager, installed in two separate airborne platforms slaved together and controlled by a single-user interface. It is expected that such a sensor system will have a direct impact on improving the response time in finding those in need of assistance or simply on increasing the performance, reliability and efficiency of crews involved in general surveillance operations.

This document explains the concept of range gating, details a preliminary performance model and describes the two generations of Canadian active imagers: ALBEDOS and ELVISS.

RÉSUMÉ

Les missions de recherche et sauvetage ainsi que celles, plus générales, de surveillance représentent de sérieux défis pour les systèmes d'imagerie conventionnels présentement utilisés par les équipages d'aéronefs. Pour repérer et identifier des cibles potentielles, ces systèmes, tels les caméras CCD, les unités avec intensificateur d'image et les imageurs thermiques, sont souvent appelés à être utilisés dans des conditions de faible éclairage et de visibilité réduite. Une nouvelle technologie d'imagerie aéroportée a été mise au point pour surmonter ces carences. Les progrès récents concernant les matrices de diodes laser, la collimation d'un faisceau d'une telle matrice et les intensificateurs d'image avec crénelage ont rendu possible la construction d'un système d'imagerie active nommé ALBEDOS (Airborne Laser-Based Enhanced Detection and Observation System). En octobre 1995, le système a été installé à bord d'un hélicoptère et testé selon divers scénarios afin d'en démontrer le potentiel. ALBEDOS a démontré son efficacité, particulièrement la nuit et dans des conditions atmosphériques détériorées. De plus, il a démontré que le crénelage en distance, qui permet déjà d'éliminer en presque totalité la rétrodiffusion causée par les aérosols, procure une certaine immunité contre les effets d'éblouissement fréquents avec les caméras de haute sensibilité.

Les présents scénarios opérationnels nécessitent une amélioration de la surveillance sur de larges étendues, une optimisation de la détection d'humains et de petits objets, et une efficacité accrue des avions de recherche. Aussi, un système de seconde génération est en voie de mise au point et combine les avantages de deux imageurs complémentaires. Ce nouveau système, ELVISS (Enhanced Low-Light Level Visible and Infrared Surveillance System), consiste en un imageur actif amélioré avec crénelage en distance couplé à un imageur thermique de haute qualité. Ces deux capteurs sont montés sur leurs plates-formes aéroportées respectives, lesquelles sont asservies ensemble et contrôlées par un seul opérateur. On s'attend à ce qu'un tel système ait un impact direct sur le temps requis pour secourir les victimes qui ont besoin de secours ou simplement sur la performance, la fiabilité et l'efficacité des équipages impliqués dans des opérations générales de surveillance.

Ce document explique le concept du crénelage en distance, détaille un modèle préliminaire sur la performance d'un système d'imagerie active et décrit les deux générations d'imageurs actifs canadiens : ALBEDOS et ELVISS.

TABLE OF CONTENTS

ABSTRACT/RÉSUMÉ i

EXECUTIVE SUMMARY v

1.0 INTRODUCTION 1

2.0 THE ALBEDOS ACTIVE IMAGER 2

3.0 ACTIVE IMAGER PERFORMANCE MODEL 5

4.0 ELVISS: A MULTISENSOR SYSTEM 10

4.1 The Thermal Camera 10
4.2 Enhanced ALBEDOS 11

5.0 DISCUSSION AND CONCLUSION 14

6.0 ACKNOWLEDGEMENTS 14

7.0 REFERENCES 15

FIGURES 1 to 10

TABLES I to IV

EXECUTIVE SUMMARY

The use of electro-optical instruments and sensors in military operations has been increasing rapidly in recent years. The overwhelming advantages enjoyed by a force that owns devices like laser rangefinders, designators, night-vision goggles, day and night cameras and thermal imagers were evident during the 90-91 Gulf War, when the US-led coalition made extensive use of these technologies. During conflicts or peacekeeping missions, the armed Forces have discovered the short-to-medium range capabilities of these optronic devices and their complementary role to radars. Today, almost all surveillance platforms are equipped with some electro-optical (E-O) sensors and, in the near future, it is expected that the active imaging systems under development today will be added to the list. Active imagers are capable of detecting and identifying targets in complete darkness and, to some extent, in adverse weather conditions. They overcome several deficiencies encountered with common CCD cameras, image intensified systems and thermal imaging sensors.

This memorandum describes two generations of Canadian airborne active imaging systems: ALBEDOS and ELVISS. The recent developments in laser diode arrays, laser diode beam collimation and gatable micro-channel plate intensifier have made it possible to build a first-generation compact active imaging demonstrator called the Airborne Laser-Based Enhanced Detection and Observation System or ALBEDOS. This system was designed and constructed under contract by a Canadian company, Wescam Inc. (Hamilton, Ontario). The project was initiated at the Defence Research Establishment Valcartier (DREV) in March 1993 and funded by the National Secretariat for Search and Rescue (NSS). ALBEDOS is an active imaging system based on a powerful pulsed laser diode array illuminator and a range-gated Low-Light Level TV (LLLTV) camera coupled to a powerful zoom lens. Because the system provides its own source of illumination, it is rather insensitive to the ambient light conditions. Also, its range-gating mode excludes the effects of backscattering that arise from haze, snow or rain present in the sensor's field of view and, in some cases, reduces significantly the blooming effect caused by the presence of bright lights. Moreover, range information is available. ALBEDOS can be operated either at night or in daytime, but is particularly efficient during overcast nights and in degraded weather conditions. It is mounted in a 24-inch diameter stabilized platform for demonstration purposes. In October 1995, flight trials were organized in collaboration with the Flight Research Laboratory of the National Research Council of Canada in Ottawa to demonstrate the potential of ALBEDOS for detection and surveillance roles and to evaluate its human-machine interface when operated by Search and Rescue (SAR) pilots. ALBEDOS was installed on a Bell 412 helicopter (equivalent to the Griffon) and several scenarios have been run. In those trials, ALBEDOS proved its ability to collect evidence-quality video in night with a mixture of bright lights and shadows, imaging of vehicle interiors at night, long-range detection of targets such as life vests with strips of retroreflective tape, and observation of vehicle lettering in the presence of running lights.

To increase the surveillance and reconnaissance capabilities over large areas of coverage, to optimize the detection of human and small objects and to enhance the effectiveness of search vehicles, the development of a second-generation airborne payload that combines the benefits of a range-gated active imager with a high-quality thermal imager was started. The Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS) consists of an improved version of ALBEDOS (added features and better performance) and a thermal imager installed on two separate airborne platforms. The complementary platforms are slaved together, viewing the same scene, and are controlled by a single user interface. This interface will be designed to optimize the combined detection capabilities. It is expected that such a sensor system will have a significant impact on the performance, reliability, response time and efficiency of crews involved in general surveillance and SAR operations.

1.0 INTRODUCTION

Canada is a large country with huge uninhabited remote territories and long coastlines where search and rescue (SAR) operations often require to cover several hundreds of square kilometers. Also, because the majority of crashed aircraft do not have working Emergency Locator Transmitters and because survival of injured people in an air crash or boat sinking decreases by 50 % after the first eight hours, any techniques aimed at improving the speed and efficiency of SAR operations, particularly combat SAR at night and in adverse weather conditions, must be thoroughly investigated. In addition, the crews in SAR missions are confronted with a significant number of tasks to which they must respond. Also, the crews who are participating in surveillance tactical operations, infiltration over hostile or denied territories and resupply of special operations forces must be ready to provide their command level with all the information required to decide whether the mission is pursued or aborted. Whatever the nature of the mission, one must assume that the information, either detection, classification or final identification, will also be available in severe weather conditions, in areas with limited accessibility and under various subject or background illumination. Up to now, these conditions along with possible interference from artificial light sources have considerably reduced the effectiveness of human observers and of passive imaging systems like CCD cameras, low-light level TV (LLLTV) systems and night-vision goggles (NVGs). Current GEN II and GEN III image intensifier technologies have long been used for surveillance applications and allow vision at moderate ranges in low-light level conditions down to the starlight level. However, these passive night vision systems cannot provide sufficient resolution and contrast in very low-light level conditions such as overcast nights or in degraded visibility conditions such as rain, fog or snow. Furthermore, they cannot provide adequate contrast in the presence of strong blooming point sources such as street lights, etc.

Other passive surveillance systems like thermal imagers or FLIRs detect mid- and far-infrared radiation and produce images based on the temperature and emissivity variations in the scene. Infrared radiation is less affected by aerosol scattering so that FLIR systems tend to perform relatively well in degraded visibility conditions. However, they do not work properly in scenes where there is little or no thermal contrast. Objects in water or registration numbers on license plates or on ships are good examples of objects that have reached thermal equilibrium with their background.

Therefore, to free the operators from some environmental constraints and to overcome many of the currently available sensors limitations, the Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS) was designed and constructed by a Canadian company, Wescam Inc. (Hamilton, Ontario). The project was initiated at the Defence Research Establishment, Valcartier (DREV) in March 1993 and funded by the National Secretariat for Search and Rescue (NSS). ALBEDOS is an active imaging system based on a powerful pulsed laser diode array illuminator and a range-gated LLLTV camera coupled to a 48X zoom lens (Figure 1) (Refs. 1 to 7). Because the system provides its own source of illumination, it is rather insensitive to the ambient light conditions. Also, its range-gating mode excludes the effects of backscattering that arise from haze, snow or rain present in the sensor's field of view (FOV) and, in some cases, reduces significantly the blooming effect caused by the presence of bright lights. Moreover, range information is available. ALBEDOS can be operated either at night or in daytime, but is particularly efficient during overcast nights and in degraded weather conditions.

ALBEDOS was mounted in a 24-inch diameter airborne stabilized platform for demonstration purposes. In October 1995, flight trials were organized in collaboration with the Flight Research Laboratory of the National Research Council of Canada in Ottawa to demonstrate the potential of ALBEDOS for detection and surveillance roles and to evaluate its human-machine interface when operated by SAR pilots. The stabilized platform and its payload was installed on a Bell 412 helicopter using a specially designed bracket and support arm (Figure 2). The instrumentation was installed on two certified 19-inch racks (Figure 3) and flight data were recorded for subsequent analysis. Several scenarios have been run through, including the ability to collect evidence-quality video in night with a mixture of bright lights and shadows, imaging of vehicle interiors at night, long-range detection of targets such as life vests with strips of retroreflective tape, and observation of vehicle lettering in the presence of running lights.

To increase the surveillance and reconnaissance capabilities over large areas of coverage, to optimize detection of human and small objects and to enhance effectiveness of search vehicles, a second-generation airborne payload is started that combines the benefits of a range-gated active imager with a high-quality thermal imager. The Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS) consists of an improved version of ALBEDOS (added features and better performance) and a thermal imager installed on two separate airborne platforms. The complementary platforms are slaved together, viewing the same scene, and are controlled by a single user interface. This interface will be designed to optimize the combined detection capabilities. It is expected that such a sensor system will have a significant impact on the performance, reliability, response time and efficiency of crews involved in general surveillance and SAR operations.

This work was carried out at DREV between October 1995 and February 1999 under Work Units 3da21: "Enhanced ALBEDOS" and 3da25: "ELVISS".

2.0 THE ALBEDOS ACTIVE IMAGER

As mentioned previously, the ALBEDOS project was initiated at DREV under the sponsorship of the National Secretariat for Search and Rescue (NSS). It was intended to enhance the search capability of SAR teams during their missions. Similarly, its surveillance capability has been investigated through various scenarios. The system was mounted on a Wescam 24-inch diameter stabilized platform for airborne operations. Figure 4 shows a picture of the internal components of the unit with one-half of the spherical enclosure removed.

ALBEDOS is a range-gated active unit capable of imaging a scene in total darkness and/or in the presence of rain, snow, haze or fog. The principle of operation of a range-gated system is illustrated in Figure 5. A laser pulse is emitted at time T=0, while the intensifier gate is closed. As the laser pulse travels through the atmosphere, it encounters various aerosols and a portion of the energy is reflected back or backscattered to the camera but the gate is still closed and no signal is detected as shown in T=1. Eventually, the laser pulse reaches the target area at time T=2, and some energy is reflected back toward the receiver while the gate is still closed. Part of this energy, after travelling again through the atmosphere, reaches the sensor at time T=4 which corresponds to the predetermined time selected by the operator to activate the gate on the intensifier in order to collect the incoming energy.

Because the gate is off during the laser pulse round trip, the amount of backscattered and/or background light is minimal. The only contribution comes from the reflected and the background energy after gate activation. This significantly increases the signal-to-noise ratio (S/N) of the intensified camera unit and therefore enhances the detection, recognition and identification capabilities of the system. Moreover, another increase in the S/N ratio, and consequently in the system performance, is obtained by triggering the laser 525 times per frame for a time-integration of the energy received by the sensor.

Without range-gating, a pulsed laser imaging system would collect all the backscattered energy from the aerosols in the illuminated FOV which would increase the noise level and consequently reduce the detection range. Therefore, the operator must judiciously select the timing for the gate activation if he wants to improve or maximize the system performance for a given scenario or mission. When operating in passive mode, the system acts as a conventional LLLTV sensor.

Figure 6 shows a schematic of the ALBEDOS basic operational components. These are a pulsed laser source, a CCD camera, a GEN-III gated image intensifier, a 48X motorized-zoom lens, a video display, a Super-VHS recorder and associated electronics. One of the main functions of the electronic components is the synchronization of the two prominent elements of the system: the laser source and the range-gated intensified camera. The time or range-gating electronic unit provides a wide selection of gate widths, pulse widths and delays for an optimal enhanced detection and observation system.

The illuminator used in ALBEDOS is based on a laser diode array source and an optical collimator to correct for the large natural divergence of the laser beam emitted by the diode array (Figure 7). The illuminator operates in the near-infrared at a wavelength of 810 nm. Two different laser beam divergences, 2 and 10 degrees, are available and can be selected by the operator. The maximum average power is around 13 W for a repetition rate of 15.75 kHz. Table I presents the main operational characteristics of the integrated illuminator. The safe operational range for this laser device, according to the nominal ocular hazard distance (NOHD) calculations, is 28 m for the naked eye and some 200 m if a 7×50 pair of binoculars is used.

TABLE I

Laser illuminator characteristics

Average power @ 15 kHz:	12.8 W
Minimum pulse length:	100 ns
Maximum pulse length:	2.0 μs
Minimum beam divergence:	1.9 × 3.2 degrees
Maximum beam divergence:	9.6 × 10.6 degrees
Wavelength (at 20°C):	810 nm
Wavelength shift:	0.4 nm/°C
Power consumption:	<150 W

The spectral response of the imaging sensor, composed of the 48X-zoom lens, the GEN III intensifier tube and the CCD camera, peaks at around 800 nanometers. Its variable gating time (from 100 ns to 2 μs) gives a possible window or range depth of 30 to 600 m with a trigger delay adjustable between 0 and 47 μs, which corresponds to a maximum operational range of 7 km. This camera, whose main characteristics appear in Table II, was built by Ball Aerospace. If the laser illuminator is turned off, this camera can be used in a passive mode of operation as a high-performance LLLTV camera. In the active mode of operation, an operator can make covert observations of scenes at large ranges unless someone uses NVGs to look in his direction. Furthermore, this camera is quite immune to dazzling by external coherent and/or incoherent light sources because it has an integrated narrow-band optical filter and is gated at a high-repetition rate with a very low duty cycle.

TABLE II

Gated-intensified camera characteristics

Intensifier gain:	30000-50000
CCD size:	750 × 480 pixels
Luminance range:	10^7 – 100 lux
Output video format:	RS-170, CCIR
Resolution:	520 TV lines @ 2×10^{-4} fc
Zoom lens:	16-800 mm focal length

The payload normally installed on the stabilized platform consists of the laser illuminator, the time-gated intensified CCD camera and the gyroscopes. The equipment outside the gimbal comprises a system interface unit, a power conditioner, a control console, a Super-VHS video recorder, a 9-inch monochrome TV monitor, a time code generator/reader and a 28-V power supply (see Figure 3).

Figures 8 to 10 are examples of the results obtained during the various trials conducted with ALBEDOS. These images were digitized on a Sun workstation using an 8-bit quantization. Each image was previously passed through a time base corrector (model DPS-275 from Digital Processing Systems Inc.). The resulting resolution was 640 × 480 pixels. Despite that processing, there were some loss in the contrast and in the general quality of these images which were copied from a Super-VHS videotape to the computer and then printed on paper. Furthermore, one should note that single images look noisier than what would actually be perceived by an operator looking at a running sequence because the brain performs image integration.

3.0 ACTIVE IMAGER PERFORMANCE MODEL

In this simple model, the active imaging system is essentially treated as a LLLTV having a scene illuminance corresponding to the illuminator power density incident on the scene. Therefore, the performance of the sensor depends primarily on the illuminator brightness with the LLLTV performance given by the noise-limited sensitivity. The model has been developed under contract by the National Optics Institute in 1996 (Ref. 8). Assuming the illuminator beam has a uniform "top hat" intensity distribution, the brightness or power density I, at a distance z, can be determined from output power P and beam divergence θ using:

$$I = \frac{P}{\theta_x \theta_y z^2} \qquad [W/m^2] \qquad (1)$$

where for a rectangular beam θ_x and θ_y are the beam divergences along the horizontal and vertical axes, respectively. Assuming that the illuminator is the only significant source of illumination, the

scene illuminance I_S can be obtained by multiplying the above relation by the atmospheric transmission T_a:

$$I_s = \frac{PT_a}{\theta_x \theta_y z^2} \qquad [W/m^2] \qquad (2)$$

where $T_a = \exp(-\alpha z)$ is the atmospheric transmission and α, the atmospheric extinction coefficient (in m^{-1}) at the illuminator wavelength of operation.

The performance of the LLLTV camera can be characterized by its noise equivalent illumination (NEI) and the signal-to-noise ratio is determined by the incident intensity on the camera multiplied by the overall system Modulation Transfer Function (MTF_s) and divided by the NEI:

$$SNR = (MTF)_s I_i / NEI \qquad (3)$$

The intensity I_i incident on the camera aperture is determined by the overlap of the camera field of view (FOV) with the reflected intensity distribution I_r of the scene. I_r is related to the scene illuminance Is by (Ref. 9):

$$I_r = I_s R C_s K T_a T_o \qquad [W/m^2] \qquad (4)$$

where R is the average scene reflectivity, C_s is the scene contrast, K is the radiance/excitance ratio ($= 1/\pi$ sr $^{-1}$ for a lambertian surface; $= 1/2\pi$ for a semi-hemispherical reflected intensity distribution), T_a is the atmospheric transmission and T_o is the lens transmission. At the camera's focal plane, the incident intensity I_i becomes:

$$I_i = \frac{I_r A_l}{f_l^2} \qquad [W/m^2] \qquad (5)$$

where A_l is the aperture area of the lens and f_l the focal length. This translates into the following relation:

$$I_i = \frac{\pi I_s R C_s K T_a T_o}{4 f\#^2} \qquad [W/m^2] \qquad (6)$$

where f# is the lens f-number that determines the camera FOV. Thus the reflected intensity distribution depends on the incident power, the scene reflectivity, the scene contrast and the diffusivity of the target (i.e. lambertian, specular, etc.).

The MTF_s represents the spatial frequency response of the imaging system and NEI is the noise equivalent illumination where SNR=1 for the input illumination I_i. A scene can be said to be imaged when the SNR is equal to or greater than 2.5, corresponding to a 50 % probability of detection for a 100 % contrast pattern (Ref. 10).

The MTF_s is the convolution of the lens MTF_l, image intensifier MTF_{ii}, CCD array MTF_c, electronics MTF_e and display MTF_d. It is assumed that the lens is well corrected and focussed, so

that diffraction-limited performance is obtained. In this case, MTF_l at a spatial frequency F, is given by the diffraction response of the system and is dependent only on the lens clear aperture D, and the wavelength λ, where (Ref. 11):

$$MTF_l = 1-(4/\pi)(\lambda F/D) \qquad (7)$$

This demonstrates that the ultimate system resolution is governed by the optics diameter and the wavelength of light. Hence, if the angular resolution requirement is smaller than the diffraction-limited point source diameter ($2.44\lambda/D$), then the scene cannot be clearly imaged. This also demonstrates the relationship between wavelength and resolution – the shorter the wavelength, the higher the resolution capability. Consequently, TV systems operating in the near-IR have inherently higher resolutions than FLIR systems operating in the IR.

The image intensifier MTF_{ii} is mainly dependent on the diameter and pitch of the microchannel plate. However, it is usually determined experimentally and appears in the manufacturer's data sheets. The CCD array MTF_c is a function of the pixel spatial frequency, $N_p = 2/a$, where a is the pixel size. The cutoff frequency is then given by the sine response to a input step function at the pixel frequency where (Ref. 12):

$$MTF_c = \frac{\sin(\pi F/2N_p)}{(\pi F/2N_p)} \qquad (8)$$

Operating at one-half the pixel frequency (typically 38 line pair/mm) results in an MTF_c of 0.9. Usually, it is necessary to reimage the image intensifier output onto the smaller CCD surface using a lens or tapered coherent fibre bundle. In this case, the CCD operating frequency is the input frequency divided by the minification of the fibre bundle or lens.

It is assumed that the readout and amplifying electronics are of suitable quality that their MTF_s are nearly unity and therefore do not impact on system performance. The display MTF_d is a Gaussian function given by (Ref. 10):

$$MTF_d = \exp - (F/F_d)^2 \qquad (9)$$

Again it is assumed that the display will be operating at less than one-half its cutoff frequency so that $MTF_d = 0.78$. Thus, the CCD and display combination have an overall MTF of about 0.7 when operated at half cutoff frequency.

In the scenario calculations, the maximum spatial frequency F_{max} for the system was set at 25 lp/mm. This value was chosen because it is the highest value for which there is image intensifier MTF data and it is close to the one-half pixel frequency for the CCD, given a minification of 0.611 for going from an 18-mm diagonal image intensifier to the 11-mm diagonal of a 2/3" CCD.

Note that the system FOV is given by the angle subtended by the image plane diagonal d, and the lens focal length f_l:

$$FOV = \arctan\left(\frac{d}{f_l}\right) \qquad (10)$$

A good scenario for evaluation is the identification of a ship by reading its name on the hull. Obsviously, the size of the letters will strongly depend on the size of the ship itself, but for the present case, we will use 50 × 20-cm letters with a contrast of one. This is a scenario which requires high resolution and good imaging performance. Because there is no temperature contrast, thermal imagers are inefficient for this type of application. Moreover, LLLTV cameras must operate in clear atmosphere with a minimum of starlight condition to be successful. A range of 1 km is assumed. According to Johnson's criteria, positive identification of an object requires a minimum spatial frequency of 8 cycles across the object's most critical dimension. Here, it is assumed that 5 cycles are enough since the objects are letters or numbers and some degree of recognition is performed by the brain. Considering the critical dimension to be the 20 cm (i.e. the width of the characters), this results in a required angular resolution of 40 μrad (at the distance of 1 km), which is 4 times larger than the diffraction limit of 10 μrad defined by the lens aperture. Using the preliminary characteristics of ELVISS listed in Table III, the above model predicts that a signal-to-noise ratio of 325 would be obtained for identification of the ship characters. For the calculations, it was assumed that the painted hull of the ship was a lambertian diffusing surface with a reflectivity of 100% and a contrast of 100%. This can be justified if white characters are painted on a dark background. The visibility is assumed at 20 km, which corresponds to an atmospheric extinction coefficient of 0.15 km^{-1}. The required angular resolution of 40 μrad corresponds to 31 lp/mm (considering a maximum focal length of 800 mm) at the image intensifier and this value is close to the limit at which some MTFs are known. Thus, calculating the S/N at a range beyond 1 km would require to know all MTFs values for spatial frequencies higher than 31 lp/mm.

TABLE III

Preliminary characteristics of ELVISS

Output power	20 W
Beam divergence	0.026 rad
Wavelength	0.81 μm
Lens transmission	0.7
Lens maximum focal length	0.8 m
Lens maximum f#	7.8
Lens diameter	0.0975 m
Lens MTF	0.74
Intensifier MTF (at 25 lp/mm)	0.07
CCD MTF	0.9
Electronics MTF	1.0
Display MTF	0.78
NEI	7.0×10^{-9} W/m^2

4.0 ELVISS: A MULTISENSOR SYSTEM

As part of the ongoing effort to improve the functionality and performance of the sensors used by SAR crews, NSS is supporting the development and construction of an Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS). It consists of an improved version of the actual ALBEDOS active imager coupled to a thermal imager installed on two separate stabilized mounts. Although the program is also supported internally by the Canadian Defence Research and Development Branch (DRDB), the spread of the project had to be limited, considering the funds's availability. For example, the dual-sensor package was originally to be mounted on a single platform; however, the excessive cost and some major technical challenges drove the program to a more reasonable size. Nevertheless, the complementary platforms, one for the enhanced active imaging system and the other for the thermal imager, will be slaved together, controlled by a single user interface. The two imaging sensors will view the same scene, but not necessarily with the same field of view (FOV). The human-machine interface will be designed to optimize the combined surveillance and reconnaissance capabilities of the two systems. The project was started in April 1998 and the final product is expected to be ready for summer 2001. Then, an important flight demonstration will take place at the Flight Research Laboratory, Ottawa, where the two platforms will be installed on a Bell 412 helicopter (civilian counterpart of the Canadian military Griffon helicopter). It is expected that ELVISS will have a significant impact on the performance, response time and efficiency of crews involved in SAR and general surveillance operations.

4.1 The Thermal Camera

The 8 to 12-μm infrared thermal imager is the Thermovision 1000 model from Agema Infrared Systems. Figure 11 is a picture of the device. It is built around a common module Sprite mercury-cadmium-telluride (HgCdTe) scanning detector (5 elements in parallel) cooled to 77 K with an integral Stirling closed-cycle microcooler. The camera is equipped with a dual-field of view lens providing either 20° (H) × 13.3° (V) or 5° (H) × 3.3° (V) total FOV. This corresponds to instantaneous FOVs (IFVOs) of 0.6 (wide FOV) or 0.15 mrad (narrow FOV), respectively. Table IV outlines the most important characteristics of the Agema camera.

TABLE IV

Characteristics of the Thermovision 1000

Detector:	
Detector type:	Sprite, 700-μm length; 5 elements in parallel
Overscan factor:	1.67
Scanned image:	
Frame frequency:	30 Hz
Line frequency:	3000 Hz
Interlace:	None
Number of IFOV/line:	565
Presented image:	
Sampling raster (H/V):	798/400
Magnification (electronic zoom):	8X
Aspect ratio:	3:2
Lens dual FOV:	
Instantaneous FOV:	0.6 mrad wide; 0.15 mrad narrow
Field of view (H × V):	20° × 13.3° wide; 5° × 3.3° narrow
Minimum resolvable temperature (MRT):	0.1° K

A camera with a continuous-zoom lens capability to match the FOV characteristics of the enhanced ALBEDOS imager would have been highly desirable. However, because of the availability of the equipment and financial constraints, at least the first version of ELVISS will be deployed with the Agema thermal imager as it is. The sensor package is already mounted on a 16-inch stabilized platform from Wescam Inc..

4.2 Enhanced ALBEDOS

The first-generation active imaging system ALBEDOS will undergo a series of modifications to either correct some of its weaknesses observed during the mumerous trials conducted in the past or to simply improve the actual capabilities of the sensor. These modifications are briefly described below and include a new laser diode illuminator, a new zoom lens with appropriate antireflection coatings, an enhanced controller to accommodate the added video tracker, a laser rangefinder, a georeferencing system and finally, an improved human-machine interface.

4.2.1 New Laser Diode Illuminator

The ALBEDOS laser diode illuminator was operating at a wavelength of 810 nm. Although in the near- infrared part of the spectrum, ALBEDOS was not perfectly covert. An observer in the line of sight of the active imager could locate the reddish spot produced by the illuminator (provided the observer was within the illuminated area of the scene). The new illuminator will operate at 855 nm, that is, more towards the infrared, and consequently, should be more covert than the initial device. The average power should reach 20 W (approximately twice

that of the original unit) with a beam divergence selectable between 2° and 15°. The laser diode array will be stabilized in temperature with the consequence that the emission spectrum will be stable in wavelength. Therefore, a narrow-band optical filter can be used in front of the intensified camera, with more rejection of the background and a concomitant increase in signal-to-noise ratio. Also, besides being slightly larger and heavier, the remaining specifications of the new laser illuminator are about the same as the ALBEDOS' first device. Finally, the small gain in atmospheric transmission when operating at 855 nm should compensate for the loss produced by a less sensitive image intensifier at this wavelength. The new illuminator is currently under development by a Canadian contractor and should be ready for integration at this end of this year.

4.2.2 New Zoom Lens

The original zoom lens was a commercial unit with antireflection (AR) coatings in the visible on all its optical elements. Unfortunately, these coatings have the opposite effect in the near infrared. The transmission at wavelengths higher than 750 nm is worse with the coatings in place than it would probably be if the optical elements had no coatings at all. At 810 nm, the transmission was less than 25%. Therefore, it was decided either to buy a new zoom lens with appropriate coatings or to dismantle the actual lens and recoat the optics. The new AR coatings will be provided at the wavelength (855 nm) of the new laser illuminator.

4.2.3 Video Tracker / Enhanced Controller

The gimbal manufacturer has received a contract to integrate a high-performance video tracker to the system. This requires modifications to the electronic controller and some electronic memory expansion. The contract is just starting.

4.2.4 Laser Rangefinder

No contract has yet been given to develop a laser rangefinder for the enhanced version of ALBEDOS. The laser rangefinder would have the dual-task of continuously providing (>5 Hz) high-resolution range to the georeferencing system and, in one specific operational mode, to automatically position the gate of the intensified camera. The latter option is part of a more general program to enhance the human-machine interface of the active imager and to automatize the system at maximum, so as to free the already overloaded operators.

4.2.5 Georeferencing System

A first contract has been given to investigate the possibility of including a georeferenced image system to ALBEDOS. The system has to be able to provide the operator with the exact position (longitude, latitude) of a contact. A laser rangefinder or the radar altimeter combined with the stabilized platform elevation data, will give the range of objects located in the center of the display. Also, the system has to be able to follow the video sequence and to give georeferenced information in real-time. With simulations, it was demonstrated, when considering all the error sources, that the resulting horizontal position error would always be less than 10 m. The feasibility study contract has ended last year and the contract to actually design and build the georeferencing system has just been approved. This work will be carried out jointly with the team in charge of the human-machine interface.

4.2.6 Human-Machine Interface

The development of ELVISS' human-machine interface (HMI) is supervised by the Defence and Civil Institute of Environmental Medecine (DCIEM), Toronto, Ontario. The work is carried out by the same contractor who conducted a similar project for ALBEDOS. The contract is just starting. The company will develop design concepts for an interface for ELVISS and will incorporate these concepts in a rapid prototype. The HMI must allow SAR personnel to use ELVISS efficiently while carrying out their other duties.

5.0 DISCUSSION AND CONCLUSION

This memorandum has presented two generations of active imaging systems whose development was sponsored by the Canadian Search and Rescue Secretariat and the Department of National Defence. The first-generation system, ALBEDOS, has demonstrated in a sequence of various airborne and ground trials its full potential to contribute directly to the Search and Rescue and Emergency Medical Service efforts. Also, its capabilities as a general surveillance sensor and its usefulness to law-enforcement and security roles have been well recognized. The system appears to complement the conventional sensor suite by allowing target-evidence gathering and positive identification of objects in complete darkness at night and in degraded weather conditions. For example, it has been demonstrated that ALBEDOS can easily read the name of a large ship at more than 1.5 km during an overcast night. In addition, the active imager has proven very effective to detect a man at more than 1 km, and also to observe features such as his type of clothing, some facial and hair characteristics, if he has luggage or a weapon, etc. The illumination of these unlit scenes at these ranges was comparable to a standard camera looking at the same scenes during daylight. It was also possible to view other objects such as vehicles and buildings, at distances greater than 3 km, depending on the size of the target. Because the system provides its own source of illumination at a wavelength at which most glasses are transparent, it was possible to image through most windows of darkened offices and vehicles.

The active imaging system is extremely sensitive to retroreflecting objects, as observed in many scenarios during airborne and ground trials. Detection tests on flexible retroreflective tape (such as those affixed on lifejackets) were successfully conducted at more than 8 km. Also retroreflections from vehicle tail lights and small bicycle reflectors were easily detected at more than 4 km. Riflescopes and binoculars were detectable at quite large distances, even though they were located 100 m inside a forest. Human eyes were detected at more than 1 km during an overcast night. In passive or low-light level TV mode, detection of these targets with retroreflective returns is impossible at these ranges.

Finally, the ALBEDOS system has proven to be quite efficient in degraded weather conditions. The range gating concept eliminates most of the light backscattered by aerosols like rain, snow or fog. Another advantage of the range gating option is, to some extent, the sensor immunity against blooming effects produced by the presence of bright lights in the scene.

This document also described the second-generation active imaging system called ELVISS. Although the project was started recently, it shows great promise for long-range nighttime identification, detection of SAR targets, markings reading and for general surveillance operations. The combination of two complementary sensors opens a lot of possibilities to be explored and exploited by SAR crews in their future missions.

6.0 ACKNOWLEDGEMENTS

The authors would like to thank Messrs. G. Tardif, D. Dubé, J. Tremblay and A. Deslauriers, for their technical assistance during the course of the ALBEDOS and ELVISS projects. They also acknowledge the support of Maj. T. Lindsey from DND's Directorate of Air Requirement (DAR).

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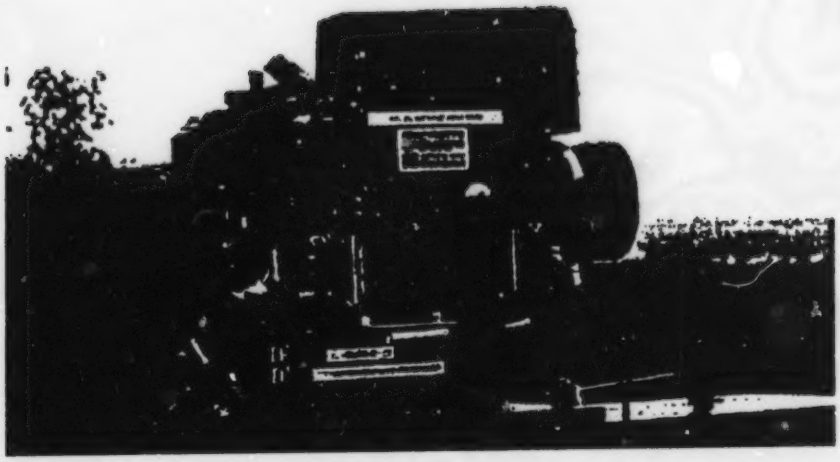


FIGURE 1 - ALBEDOS sensor without the stabilized platform

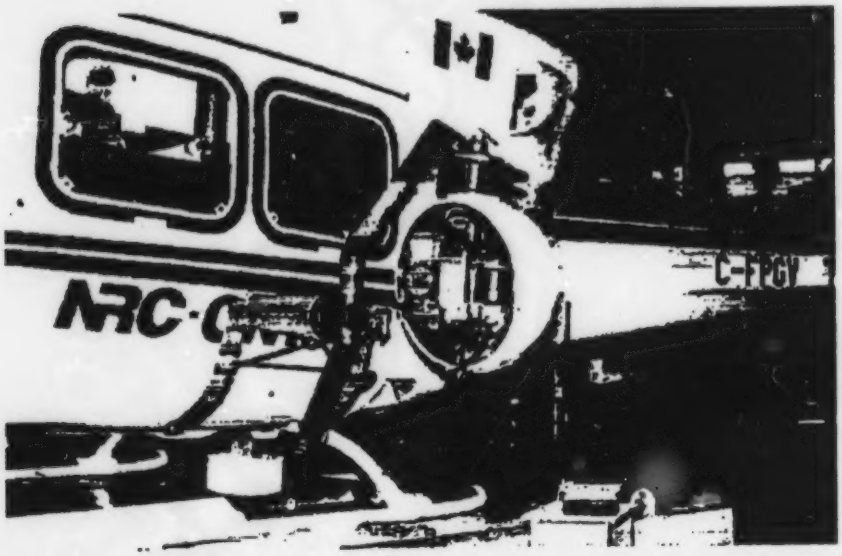


FIGURE 2 - Bracket and support arm for the installation of the 24-inch stabilized platform on the Bell 412 helicopter

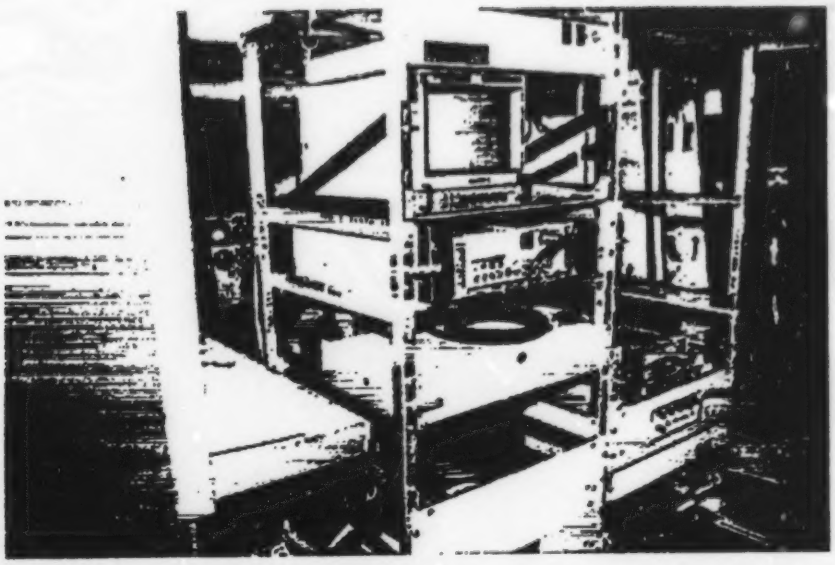


FIGURE 3 - ALBEDOS instrumentation inside the helicopter cabin

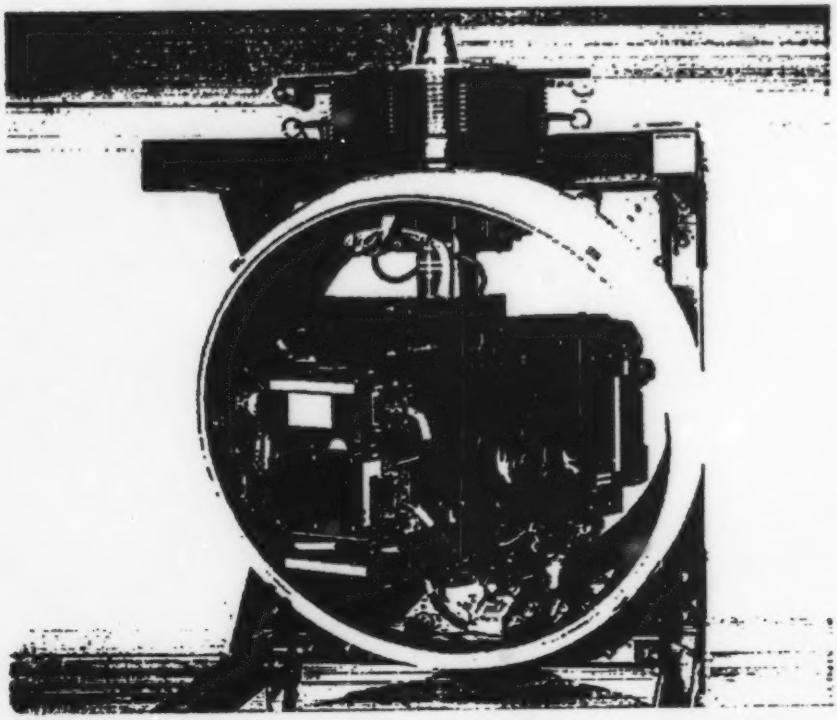


FIGURE 4 - The ALBEDOS sensor in its 24-inch gimbal

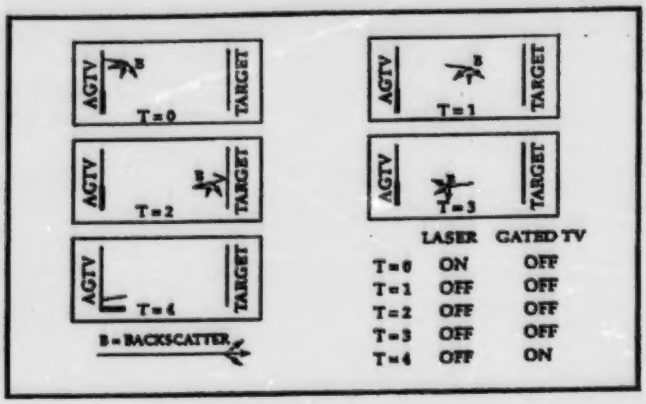


FIGURE 5 - Principle of range-gated imaging

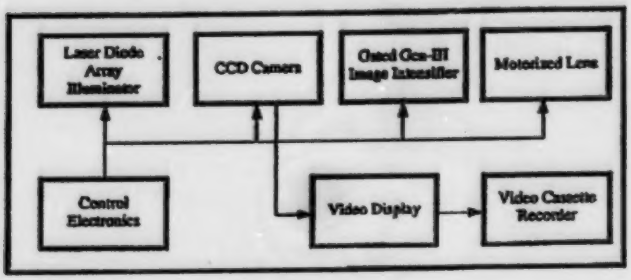


FIGURE 6 - ALBEDOS basic schematic diagram

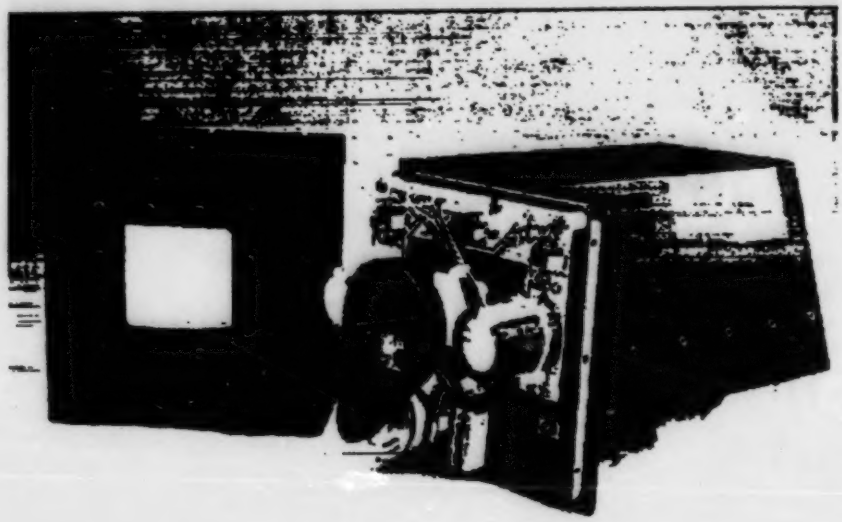
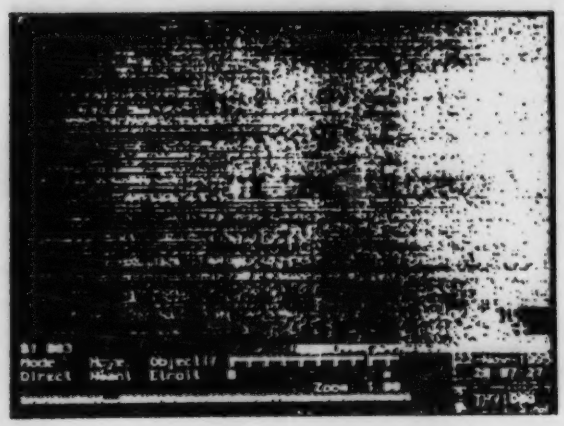
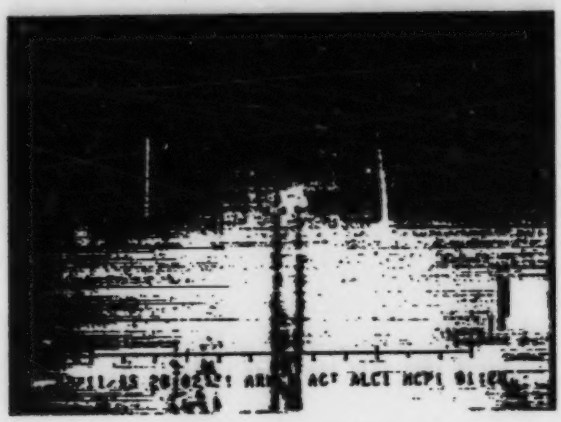


FIGURE 7 - Laser diode array illuminator

a) LLLTV camera



b) 8-12 μm thermal imager (FLIR)



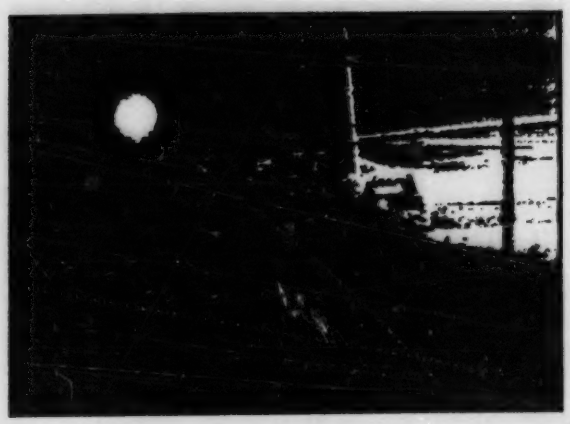
c) ALBEDOS (range gating mode)

FIGURE 8 - Comparison of various sensors. Scene consists of two men and a vehicle between two wooden poles at 420 m during a snowfall at night.

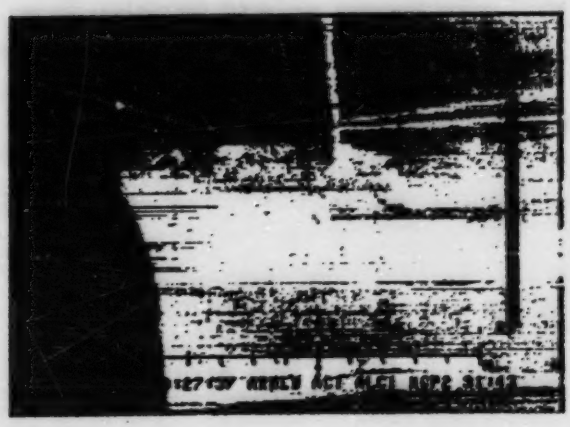
a) passive mode (illuminator off)

b) active mode (illuminator on)

FIGURE 9 - Comparison of passive and active modes. Scene consists of a man standing between two large wooden panels at 900 m (overcast night).



a) passive mode (note the blooming effect produced by the bright light on the bow)



b) active mode

FIGURE 10 - Showing the effect of blooming on identification in active and passive modes. Scene consists of a ship at 1100 m (overcast night).

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arch and rescue (SAR) and general surveillance missions pose a serious challenge to conventional imaging systems used by current aircraft crews. ees systems, which include common CCD cameras, image intensifier devices and thermal imaging sensors, must often work in low-light level and low-ibility conditions to find and identify targets. A new airborne imaging technology has been designed to overcome several of these limitations. The recent velopments in laser diode arrays, laser diode beam collimation and gatable micro-channel plate intensifiers have made it possible to build a compact tive imaging system, called the Airborne Laser-Based Enhanced Detection and Observation System (ALBEDOS). To demonstrate its potential, the stem was installed on a helicopter and tested in various scenarios in October 1995. ALBEDOS proved particularly efficient at night and in degraded eather conditions. In addition, it was demonstrated that range gating, aside from eliminating most of the light backscattered by aerosols, provided near-al immunity to blooming effects, particularly in situations where conventional highly sensitive cameras are blinded.

e current operational scenarios require to enhance surveillance capability over large areas of coverage, to optimize the detection of humans and small jects and improve the effectiveness of the search aircraft. Thus, a second-generation system is currently developed and combines the benefits of two mplementary imaging sensors. The Enhanced Low-light level Visible and Infrared Surveillance System (ELVISS) consists of an improved range-gated tive imager and a high-quality thermal imager, installed in two separate airborne platforms slaved together and controlled by a single-user interface. It is pected that such a sensor system will have a direct impact on improving the response time in finding those in need of assistance or simply on increasing performance, reliability and efficiency of crews involved in general surveillance operations.

is document explains the concept of range gating, details a preliminary performance model and describes the two generations of Canadian active agers: ALBEDOS and ELVISS.

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